AMP Global Optoelectronics

HiPPI - 6400:
Creating an Eye-Safe Parallel Optical Interconnect

ABSTRACT

At the February HiPPI - 6400 Optical Working Group meeting in San Jose, AMP proposed an optical link budget which would lead to a Class 1 laser parallel data link in the U.S. and a Class 3a link outside of the U.S.

A number of questions were raised with regard to requirements for Class 3a laser products and methods used to guarantee eye safety in the absence of an Open Fiber Control (OFC) circuit. This white paper is intended to further define the AMP link budget proposal and to address the issues related to Class 1/3a laser operation and the deployment of such products in data communications systems.

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NOTICE

BACKGROUND

At the August '96 HiPPI - 6400 meeting in Honolulu, work commenced on writing a specification for a parallel optical interconnect. The two key issues identified at that time for advancing the specification were selection of an optical connector ferrule and identification of an optical link budget that would meet the applicable laser safety requirements. The MT ferrule was selected at the October meeting but as of the January meeting, little progress had been made toward resolving the laser safety issues.

During the January meeting, AMP made a proposal intended to achieve the following goals:

1) Guarantee that the data link meets all applicable laser safety requirements.
2) Ensure that adequate power is launched into the fiber to satisfy the optical link budget criteria.

The proposal described a solution which would provide a Class 1 laser array data link in the U.S., and a Class 3a product for the rest of the world.

LASER SAFETY

Requirements in the U.S.

Laser products to be sold and deployed in the U.S. must conform to CDRH 21 CFR Ch. 1 Subchapter J Part 1040.10. Applicable categories for an 850nm communication grade laser are Class 1 or Class 3b. Class 1 lasers are considered to be non-hazardous. Safety related performance requirements for such devices are minimal. The main provision is that the user's manual contain certain basic information describing the laser's operating characteristics, maintainance and service procedures, and instructions for safe use of the laser.

Direct radiation from Class 3b lasers is considered to be an acute hazard to the skin and eyes. Such lasers are usually not deployed in commercial or industrial premises unless additional safety controls are applied. Examples of such controls include protective housings, safety interlocks, key controls, and/or beam attenuators. When appropriate controls are used, a Class 3b laser *component* can be deployed as part of a Class 1 laser *system* since during operation, Class 3b emission levels are not accessible to the system operator.

An example of such a system would be one which employs Open Fiber Control (OFC) as defined by the ANSI X3T11 Fibre Channel standard. OFC serves as a redundant safety interlock which allows Class 1 operation of a Class 3b component. OFC has not proven to be a popular alternative due to the added cost and complexity of adding an OFC compliant chipset to each link. The proposed 2nd and 3rd generation revisions of the Fibre Channel standard have provided for non-OFC implementations for shortwave data links by specifying lower launched power levels.

Requirements outside the U.S.

Laser products to be sold and deployed outside of the U.S. need to conform to the IEC 825-1 document. An additional document, IEC 825-2, provides further guidelines on the deployment of optical fiber communication systems. Appropriate designations for an 850 nm communication grade laser are Class 1, 3a, or 3b. Class 1 accessible emission limits (AEL) for an 850 nm laser array are more stringent for the IEC document than for the CDRH document. It is therefore possible that a laser may meet the requirements for Class 1 in the U.S. but not in other countries.

IEC 825 -1 Class 1 is not a viable category for an 850 nm 12 channel laser array transmitter due to the very low power levels allowed. This would place demands on the receiver which can not be readily met with today's integrated circuit technology. A summary of maximum allowed coupled power per fiber vs. NA for a 12 fiber array is given in Table 1.

Table 1 - Maximum allowed power per fiber for 12 fiber array (820 nm, 250 μm pitch)

Numerical Aperture	CDRH Class 1	IEC Class 1	IEC Class 3a	Units
0.15	-8.5	-11.4	-4.4	dBm
0.2	-6	-9.7	-2.7	dBm
0.275	-3.3	-7.5	-0.5	dBm

The Class 3a designation was added to accommodate lasers that are safe when viewed with the unaided eye but may be hazardous when viewing is assisted by an optical instrument such as a microscope. This category provides a transition between Classes 1 and 3b which allows up to five times (7 dB) more power than Class 1.

<u>Application of Class 3a to 850 nm lasers does not require a questionable interpretation of IEC 825-1 as has been previously implied. Table 3 on page 63 very clearly shows the equations for determining the accessible emission limit for lasers operating in the 700 to 1050 nm range. The textual description for Class 3a from section 9.2 is as follows:</u>

> "**Class 3a:** Lasers which are safe for viewing with the unaided eye. For laser emitting in the wavelength range from 400 to 700 nm, protection is afforded by aversion responses including the blink reflex. For other wavelengths the hazard to the unaided eye is no greater than for Class 1. Direct intrabeam viewing of Class 3a lasers with optical aids (e.g. binoculars, telescopes, microscopes) may be hazardous."

The performance requirements for a Class 3a laser system can be summarized as follows:

1) If the system is located in an unrestricted environment, a specialized tool is required to unmate any optical connectors. Systems located in an area restricted to the general public , such as a commercial office, do not require the use of such a tool.
2) The transmit port and any subsequent connectors must have the appropriate labels as described in the IEC document. Groups of connectors in a common location (such as in a patch panel) do not require individual labeling.

Additionally, operation manual requirements are similar to those described for the CDRH document in the above paragraphs.

Class 3a is a relatively unfamiliar category for many systems suppliers. Some education will be required to bring about a general awareness of the benefits of Class 3a. As the following section will show, the primary benefit is higher launched power compared to Class 1 without the requirement of OFC or complicated mechanical means for limiting access to the laser radiation. This will lead to a data link solution which can be reliably manufactured by the component suppliers and will provide an optical link budget that will meet the needs of the systems suppliers.

OPTICAL LINK BUDGET

In order to develop a link budget for a fiberoptic data link, there are four basic factors which must be considered:

1) What is the maximum optical power which can be coupled into the fiber while still meeting all applicable laser safety requirements?
2) What coupled power range is needed in order to account for part to part differences in coupled power during manufacturing and variations in coupled power over time and temperature during operation?
3) How large does the link budget need to be in order to ensure operation over the required link length?
4) What is the receiver (Rx) sensitivity for a given bit error rate (BER)?

There are certain parameters that are essentially fixed such as the eye safe coupled power or the minimum link budget necessary to meet a given link length. Other parameters may be traded off against each other in order to reach a design that lends itself to ease of manufacture. For example, receiver sensitivity requirements could be relaxed by reducing the transmitter (Tx) coupled power range. Coupled power range is defined as the maximum coupled power which meets the eye safety requirements minus the minimum coupled power necessary to satisfy the link budget.

The initial AMP proposal suggested a maximum coupled power of -6 dBm/fiber with a minimum numerical aperture of 0.2. These numbers are based on the laser safety calculations for a CDRH Class 1 laser product. This leads to questions about how the specification would account for differences between the maximum power coupled into a fiber and the maximum emitted power with the fiber removed (also refered to as “open bore”). The concern is that by specifying -6 dBm maximum coupled power, it is possible that a particular transmitter may not be eye safe when the fiber is removed from the transmitter port.

The solution to this problem is largely dependent on the optical subassembly (OSA) design for a given transmitter. Examples of different approaches include micro-lenses, fiber stubs, or planar waveguides. If a particular design has a very high coupling efficiency, then the difference between the fiber coupled and open bore power levels will be very small and can be easily absorbed within the coupled power range. If the coupling efficiency is small, perhaps 50% for example, then a 3 dB difference could exist between coupled and open bore powers and the coupled power range will be diminished by the same amount.

Since each manufacturer will have a different OSA design, the logical action is to remove the maximum coupled power parameter from the specification and simply state that the laser transmitter must meet laser safety requirements as dictated by the IEC and CDRH documents .

If more than this is specified, the risk is created of placing unneccesary burdens on the designers and manufacturers of optical subassemblies. For example, a particular design may couple greater than -6 dBm into the fiber however if the NA is larger than 0.2, then laser safety requirements would still be satisfied. Laser safety compliance tests are conducted on open bore components. If a laser is determined to be eye safe under these conditions, then it will be eye safe with fiber plugged in under all foreseeable circumstances.

The proposal to remove the maximum launch power is not without precedent. At the January IEEE 802.3z Gigabit Ethernet meeting in San Diego, a motion was passed to remove the maximum coupled power parameter from the draft specification and create a reference to the laser safety documents.

The minimum launch power may be kept at - 12 dBm as in the original proposal. This would provide approximately 6 dB coupled power range for a 0.2 NA part with 100% coupling efficiency. For smaller values of NA or lower coupling efficiency, this range will be reduced. This puts the challenge on the optical designers to come up with a controlled NA, highly efficient OSA design. The revised proposal is summarized in Table 2.

Table 2 - Proposed Optical Link Budget and Related Parameters

Parameter	Units	Value
Max. Tx Coupled Power[1,2]	dBm	xxx
Min. Tx Coupled Power[1]	dBm	-12
Optical Link Budget[3]	dB	6
Rx Sensitivity[4]	dBm	-18

1 - Power coupled into 62.5µm multimode fiber.
2 - Max. coupled power must conform to IEC 825-1 requirements for Class 3a laser product and CDRH CFR 21 Ch. 1(J) Part 1040.10 for Class 1 laser product.
3 - Allows operation to 275 m over 62.5 µm MMF at 1.0 Gb/s/channel.
4 - Rx sensitivity at 10^{-12} bit error rate.

SUMMARY

An overview of the requirements for Class 1 (U.S) and Class 3a (non-U.S.) laser products has been provided. An optical link budget has been proposed which falls within the boundaries of both national and international safety standards without requiring the use of Open Fiber Control circuitry. By adopting this proposal as a basis for moving forward, progress can be made toward writing a specification for an optical interconnect for HiPPI - 6400 in a timely manner.

REFERENCES

1) Center for Devices and Radiological Health (CDRH) 21 CFR Ch. 1 Subchapter J Part 1040.10, "Performance Standards for Light Emitting Products", 4/94.
2) International Electrotechnical Commission (IEC) 825 - 1 "Safety of Laser Products Part 1: Equipment Classification, Requirements, and User's Guide", 11/93
3) IEC 825-2 "Safety of Laser Products Part 2: Safety of Optical Fiber Communication Systems", 9/93
4) Warren Lewis, AMP Program Manager, "Eye safety calculations for 12 fiber ribbon coupled array transmitters", 10/96
5) Warren Lewis, private conversation, 1/97